NATIONAL JUNIOR COLLEGE

SENIOR HIGH 2 PRELIMINARY EXAM

Higher 2

CANDIDATE NAME

SUBJECT CLASS

REGISTRATION NUMBER

PHYSICS
Paper 3 Longer Structured Questions
Candidate answers on the Question Paper.

No Additional Materials are required.

9749/03

25 Aug 2023
2 hours

READ THESE INSTRUCTION FIRST
Write your subject class, registration number and name on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

The use of an approved scientific calculator is expected, where appropriate.

Section A
Answers **all** questions.

Section B
Answer **one** question only.

You are advised to spend one and a half hours on Section A and half an hour on Section B.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
Section A	
1	**/ 7**
2	**/ 10**
3	**/ 9**
4	**/ 10**
5	**/ 8**
6	**/ 6**
7	**/ 10**
Section B	
8	**/ 20**
9	**/ 20**
Total (80m)	

This document contains **28** printed pages and **4** blank pages.

Data

speed of light in free space	$c = 3.00 \times 10^{8}\,\mathrm{m\,s^{-1}}$
permeability of free space	$\mu_0 = 4\pi \times 10^{-7}\,\mathrm{H\,m^{-1}}$
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}\,\mathrm{F\,m^{-1}}$
	$(1/(36\pi)) \times 10^{-9}\,\mathrm{F\,m^{-1}}$
elementary charge	$e = 1.60 \times 10^{-19}\,\mathrm{C}$
the Planck constant	$h = 6.63 \times 10^{-34}\,\mathrm{J\,s}$
unified atomic mass constant	$u = 1.66 \times 10^{-27}\,\mathrm{kg}$
rest mass of electron	$m_e = 9.11 \times 10^{-31}\,\mathrm{kg}$
rest mass of proton	$m_p = 1.67 \times 10^{-27}\,\mathrm{kg}$
molar gas constant	$R = 8.31\,\mathrm{J\,K^{-1}\,mol^{-1}}$
the Avogadro constant	$N_A = 6.02 \times 10^{23}\,\mathrm{mol^{-1}}$
the Boltzmann constant	$k = 1.38 \times 10^{-23}\,\mathrm{J\,K^{-1}}$
gravitational constant	$G = 6.67 \times 10^{-11}\,\mathrm{N\,m^2\,kg^{-2}}$
acceleration of free fall	$g = 9.81\,\mathrm{m\,s^{-2}}$

Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
work done on/by a gas	$W = p\Delta V$
hydrostatic pressure	$p = \rho gh$
gravitational potential	$\phi = -Gm/r$
temperature	$T/\text{K} = T/°\text{C} + 273.15$
pressure of an ideal gas	$p = \dfrac{1}{3}\dfrac{Nm}{V} < c^2 >$
mean translational kinetic energy of an ideal gas molecule	$E = \dfrac{3}{2}kT$
displacement of particle in s.h.m.	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$ $= \pm \omega \sqrt{x_0^2 - x^2}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \ldots$
electric potential	$V = \dfrac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage	$x = x_0 \sin \omega t$
magnetic flux density due to a long straight wire	$B = \dfrac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	$B = \dfrac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_0 nI$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \dfrac{\ln 2}{t_{\frac{1}{2}}}$

Section A

1 A bungee jumper of mass 60 kg is attached to an elastic rope which starts to stretch after a short time of free fall. The gravitational potential energy of the bungee jumper is 0 J when she has fallen through 40 m to the lowest point.

(a)

	gravitational potential energy / kJ	elastic potential energy / kJ	kinetic energy / kJ
top		0	0
half-way		2.6	
bottom	0		

Fig. 1.1

Fill up the missing energies at the top, bottom and half-way positions in Fig 1.1. Drag forces can be considered negligible. [2]

(b) Show that the unstretched length of the elastic rope is 10 m.

[2]

(c) Determine at what extension will the kinetic energy of the bungee jumper be the highest.

extension = ……………………….. m [3]

[Total: 7]

2 Fig. 2.1 shows a small conducting sphere suspended from a long insulating thread between two metal plates M and M' that are 0.0500 m apart. The plates are connected to a 5.0×10^3 V battery. The sphere has a radius of 0.0025 m and a mass of 1.0 g.

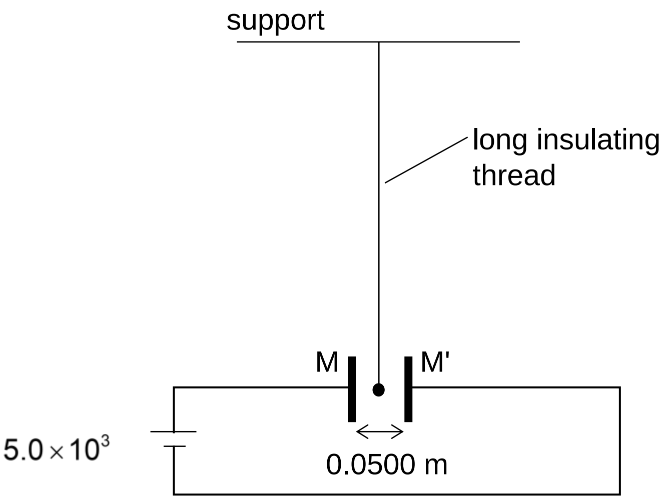


Fig. 2.1

The sphere is given an initial displacement such that the sphere touches M. It then moves rapidly to M', touches it, and returns rapidly to M again. This process repeats itself.

(a) State and explain why an initial displacement to touch one of the plates is necessary for the process to start.

....

....

.... [2]

(b) When the sphere touches either plate, it acquires a potential that is equal to the potential difference between the plates.

The electrical potential on the surface of a charged conducting sphere can be determined by assuming that all its charges are accumulated at the centre of the sphere.

Show that the charge on the sphere when it touches M is $50\pi\varepsilon_o$.

[1]

(c) If the electric field between the plates is uniform, calculate the magnitude of the electrostatic force acting on the sphere.

force =……………..……….. N [1]

(d) As a long thread is used, the motion of the sphere is nearly horizontal and is due to electrostatic force only. Determine the time taken for the sphere to move from M to M'.

time taken =………………. s [3]

(e) When the battery is removed from Fig. 2.1, the plates remain equally but oppositely charged. The sphere is totally discharged and given an initial displacement to enable it to reach one of the plates. State and explain how the time taken to move from one plate to the other will change.

…………………………………………………………………………………………………..

…………………………………………………………………………………………………..

…………………………………………………………………………………………………..

…………………………………………………………………………………………………..

………………………………………………………………………………………………… [3]

[Total: 10]

3 **(a)** A student wanted to light a lamp, but only had available a 12 V battery of negligible internal resistance. In order to reduce the battery voltage, he connected the circuit as shown in Fig. 3.1. The maximum value of the resistance of the rheostat XY was 1000 Ω.

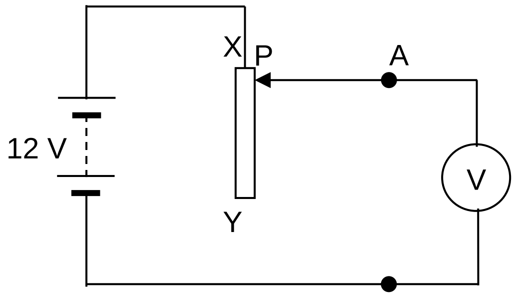


Fig. 3.1

He found that, when the sliding contact P of the rheostat was moved down from X to Y, the voltmeter reading dropped from 12 V to 11 V.

Calculate the resistance of the voltmeter.

resistance = ... Ω [2]

(b) He modified the above circuit into the one shown in Fig. 3.2 below, using the rheostat as a potentiometer, and was now able to adjust the rheostat to give a voltmeter reading of 3.0 V.

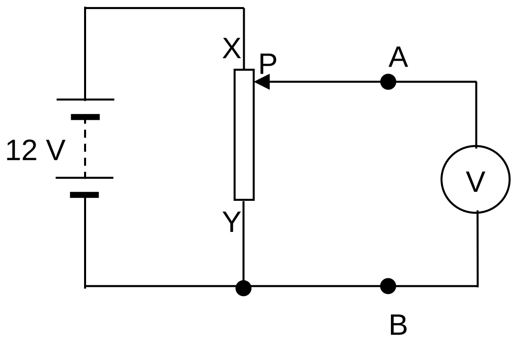


Fig. 3.2

(i) Calculate the current that flows through the voltmeter.

current = ... A [1]

(ii) Assuming that the current in **(i)** is negligible compared with the current through the rheostat, determine how far down from X the sliding contact P would have been moved.

Express your answer as a fraction of the length of XY.

fraction of the length of XY = ... [2]

(iii) The student then removed the voltmeter in Fig.3.2 and then connected a lamp rated at 0.60 W, 3.0 V in its place, but it was very dim.

By calculating the power delivered to the lamp, explain this observation.

....

....

....

....

.... [4]

[Total: 9]

4 **(a)** **(i)** Explain what is meant by the *diffraction* of a wave.

………………………………………………………………………………………………………

……………………………………………………………………………………………… [1]

(ii) State an important condition for significant diffraction to occur.

……………………………………………………………………………………………… [1]

(b) A diffraction grating with 300 lines per millimeter is being used in a typical light experiment. Different types of light are allowed to fall normally on a diffraction grating and the resultant pattern formed is to be studied. The first light source to be studied is a white light consisting of wavelengths between 400 nm and 700 nm

(i) Determine the maximum order of the complete spectrum that can be observed.

maximum order = ……………….. [2]

(ii) Determine the order of the complete spectrum before the first overlapping between two higher order spectra.

order = …………………. [3]

(c) The next experiment is of light from a low pressure sodium lamp. Light from the lamp consists mostly of two wavelengths, 588.99 nm and 589.59 nm.

(i) Explain quantitatively the problem that would likely arise in observing the spectral lines.

....

.... [2]

(ii) Suggest a refinement to the set up to help overcome this problem.

....

.... [1]

[Total: 10]

5 **(a)** Define *magnetic flux density*.

....

....

.... [1]

(b) Negatively-charged particles are moving with speed v through a vacuum in a parallel beam. The particles enter a region of uniform magnetic field of flux density 930 μT. Initially, the particles are travelling at right-angles to the magnetic field. The path of a single particle is shown in Fig. 5.1.

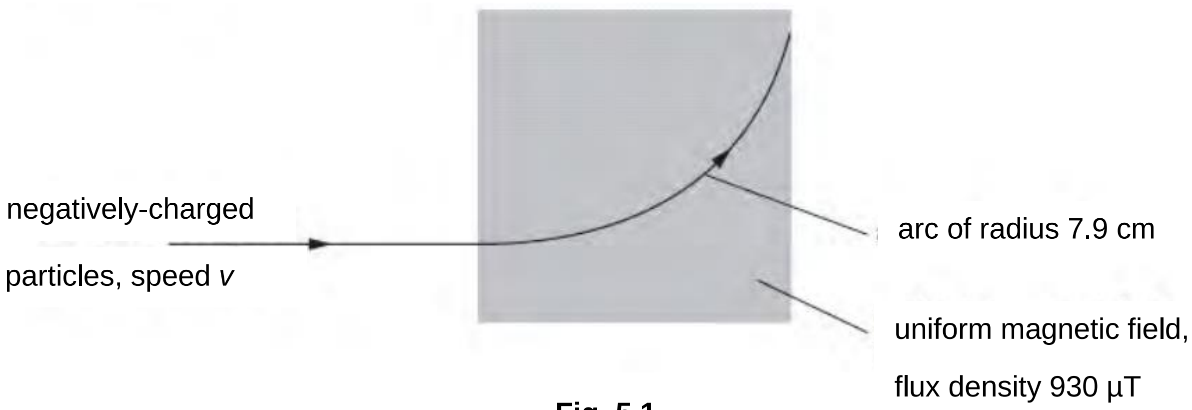


Fig. 5.1

The negatively-charged particles follow a curved path of radius 7.9 cm in the magnetic field.

A uniform electric field is then applied in the same region as the magnetic field. For an electric field strength of 12 kV m^{-1}, the particles pass through the region of the fields without deviation.

(i) On Fig. 5.1, mark with an arrow the direction of the electric field. [1]

(ii) Calculate the speed v.

v = ... m s^{-1} [3]

[Turn over

(iii) Calculate the $\frac{\text{charge}}{\text{mass}}$ ratio of the negatively-charged particles.

ratio = ……………………………… C kg^{-1} [3]

[Total: 8]

6 Fig. 6.1 shows a simple transformer consisting of a primary coil of 25000 turns and a secondary coil of 625 turns.

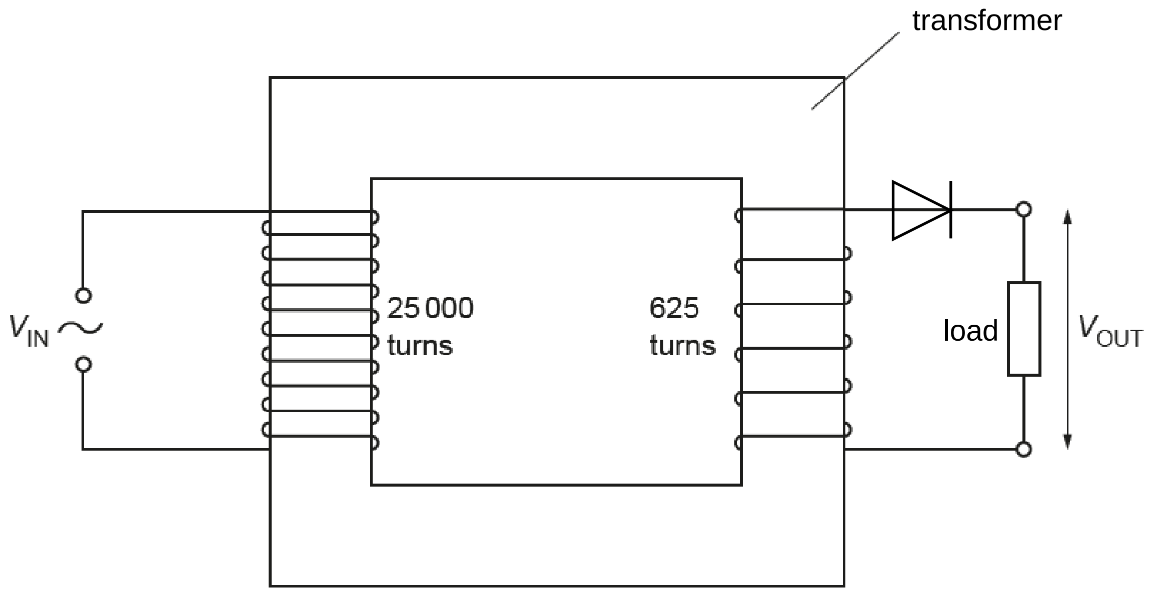


Fig. 6.1

The primary coil is connected to an alternating voltage V_{IN} which is represented by the equation

$$V_{IN} = 220 \sin(120\pi t)$$

The secondary coil is connected to a diode and a load in series. The voltage across the load is V_{OUT}.

(a) Calculate the r.m.s. value for V_{OUT}.

r.m.s. V_{OUT} = ... V [3]

(b) An electrician mistakenly connected the diode to the primary circuit instead as shown in Fig. 6.2.

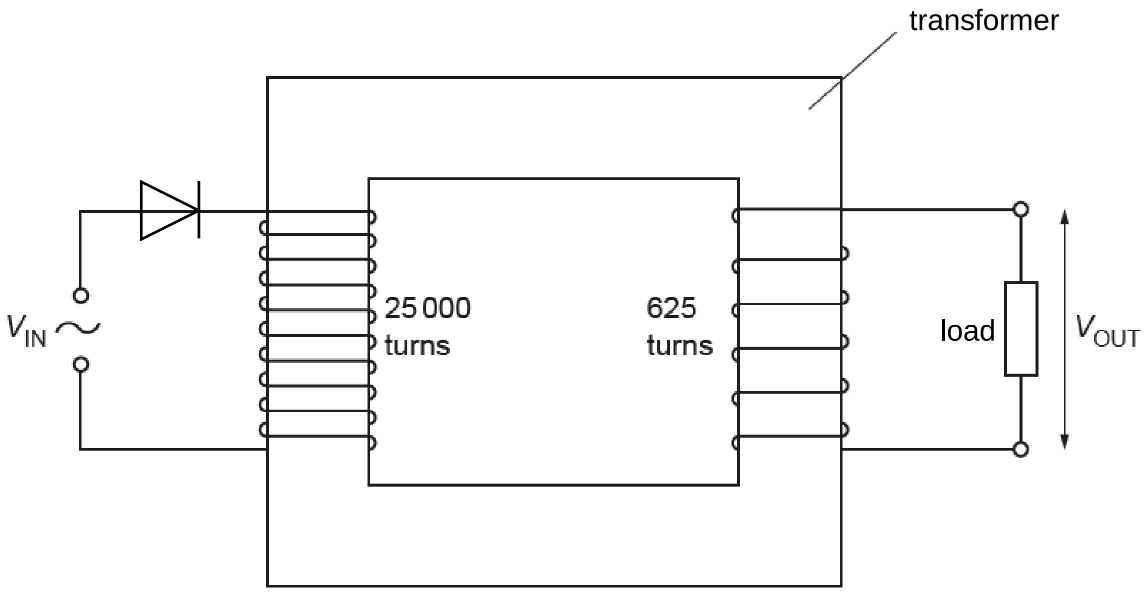


Fig. 6.2

The load requires a direct current to flow in it to operate properly. However, due to the mistake, an alternating current flow in it instead and the load fails to operate properly.

Use Lenz's Law to explain why an alternating current instead of a direct current would flow in the load.

....

....

....

....

....

....

.... [3]

[Total: 6]

7 **(a)** The emission spectrum of atomic hydrogen consists of a number of discrete wavelengths. Explain how this observation leads to an understanding that there are discrete electron energy levels in atoms.

....

....

....

....

.... [2]

(b) Three electron energy levels in atomic hydrogen are represented in Fig. 7.1.

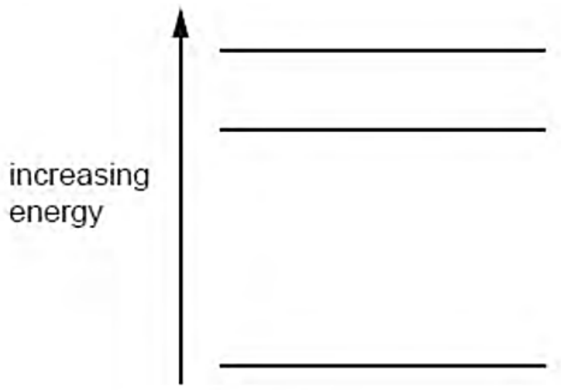


Fig. 7.1

The wavelengths of the spectral lines produced by electron transitions between these three energy levels are 486 nm, 656 nm and 1880 nm.

(i) On Fig. 7.1, draw arrows to show the electron transitions between the energy levels that would give rise to these wavelengths.
Label each arrow with the wavelength of the emitted photon. [3]

(ii) Calculate the maximum change in energy of an electron when making transitions between these levels.

energy = ... J [2]

(iii) When an electron undergoes transition, there is a change in momentum of the hydrogen atom.

1. Explain the origin of the change in momentum of the hydrogen atom.

....

....

....

.... [2]

2. For the electron transition in **(ii)**, calculate the change in momentum of the hydrogen atom.

change in momentum = ... kg m s^{-1} [1]

[Total: 10]

Section B

Answer **one** question from this Section in the spaces provided.

8 In a power station generator, a large rectangular coil is rotating at 50 revolutions per second in a magnetic field of magnetic flux density of 0.29 T. The coil as shown in Fig. 8.1 has 38 turns each 2.0 m long and 1.2 m wide.

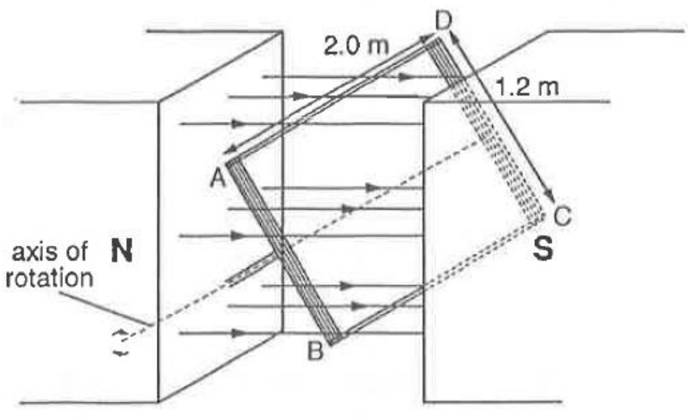


Fig. 8.1

The maximum output e.m.f. of the coil occurs when it moves near the plane of the magnetic field as shown in Fig. 8.2.

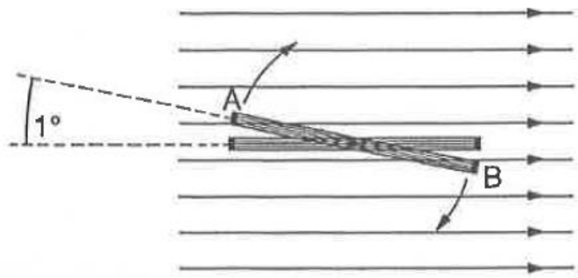


Fig. 8.2

(a) State Faraday's law of electromagnetic induction.

………...

……….. [1]

(b) For the coil moving through an angle of 1.0° near the plane of the magnetic field, calculate

(i) the time taken for it to rotate 1.0°

time = ………………..s [2]

(ii) the flux cut by one turn of the coil in this time

flux cut = …………..Wb [3]

(iii) the e.m.f. generated by one turn of the coil in this time

e.m.f. = ………………V [2]

(iv) the e.m.f. generated by all 38 turns of the coil in this time

e.m.f. = ………………V [1]

(c) **(i)** The value obtained in **(b)(iv)** is the peak value of the sinusoidal output of the coil. Calculate the r.m.s. value of the output of the coil.

r.m.s. value of the output = …………….V [1]

(ii) State the direction of the current induced in side AD as a result of this e.m.f. Explain how you deduced your answer.

……

……

……………………………………………………………………………………………………… [2]

(d) (i) State *Lenz's* law.

……

……………………………………………………………………………………………………… [1]

(ii) Explain the following two situations, using the laws of electromagnetic induction:

1. A copper disc spins freely between the poles of an unconnected electromagnet as shown in Fig. 8.3.

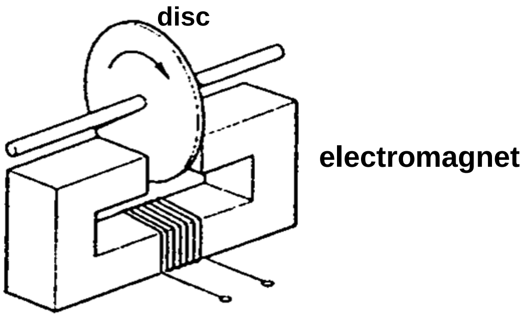


Fig 8.3

Describe and explain what will happen to the speed of rotation of the disc when a direct current is switched on in the electromagnet.

……

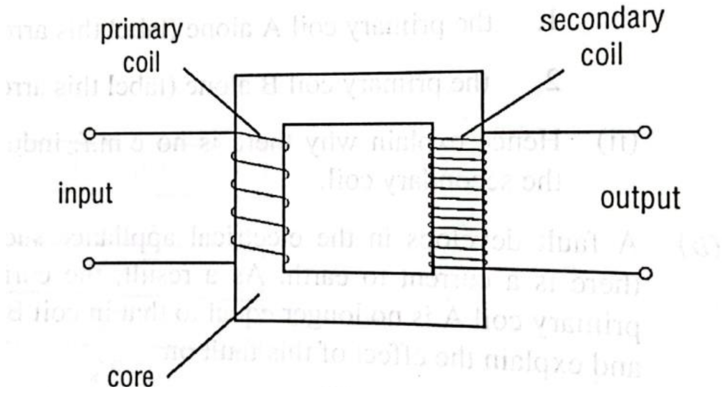
……

……

……

……………………………………………………………………………………………………… [4]

2. A simple iron-cored transformer is shown below.



Suggest why the input voltage and the output e.m.f. have the same frequency.

....

....

....

.... [3]

[Total: 20]

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9 Some elements that are normally stable, such as lead (Pb), have isotopes which are radioactive. The nucleus $^{214}_{82}Pb$ is one such isotope of lead.

(a) State what is meant by isotopes.

……...

……...

…….. [2]

(b) A nucleus of $^{214}_{82}Pb$ decays by β emission into $^{214}_{83}Bi$. This bismuth nuclide is itself radioactive with an unusual decay pattern. Sometimes it decays by α emission into tellurium (Tl) and sometimes by β emission into polonium (Po). Write the nuclear equations for these two decays of $^{214}_{83}Bi$.

α emission: ……………………………………………………………………………………….…………

β emission: ……………………………………………………………………………….………… [2]

(c) The two decay patterns of the $^{214}_{83}Bi$ each give rise to γ ray photons. Suggest why each of these photons have different energies.

……...

……...

………………………………………………………………………………………….................. [2]

(d) A stationary $^{214}_{82}Pb$ decays by β emission into $^{214}_{83}Bi$ as shown in Fig. 9.1.

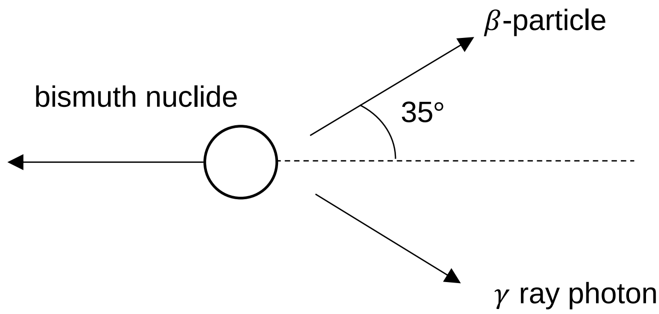

Fig. 9.1

The energy of the β-particle is 0.74 MeV and the energy of the bismuth nuclide is 5.5 eV.

(i) Determine the momentum of

1. the β-particle

momentum =...................................... kg m s^{-1} [1]

2. and the bismuth nuclide

momentum =...................................... kg m s^{-1} [1]

(ii) Hence, using the principle of conservation of linear momentum show that the wavelength of the γ ray photon is 1.36 pm.

[4]

(e) At time t = 0 s, a sample consists only of the isotope $^{214}_{82}Pb$.

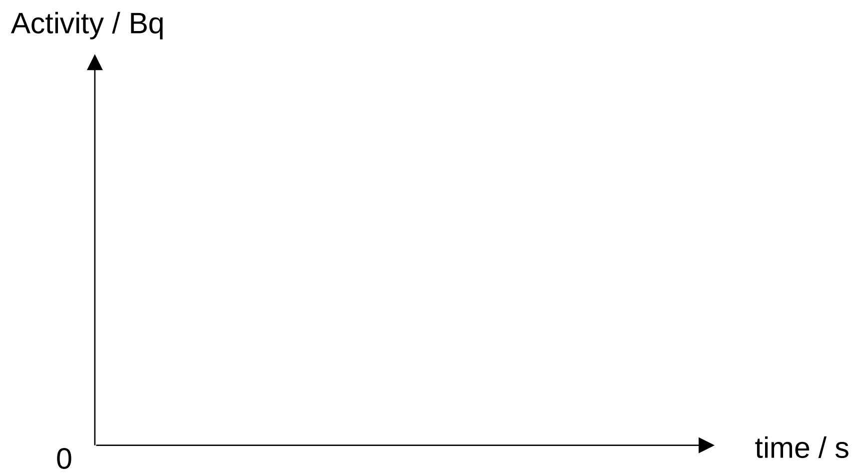

Fig. 9.2

(i) Without numerical values, sketch on Fig. 9.2 a graph of the activity of $^{214}_{82}Pb$ with time. Label this graph Pb.

[1]

(ii) Without numerical values, sketch on Fig. 9.2 a graph of the activity of $^{214}_{83}Bi$ with time. Label this graph Bi.

[2]

(f) A sample of $^{214}_{82}Pb$ has mass 3.5 μg at time t = 0 s. The half-life of $^{214}_{82}Pb$ is 27 minutes.

(i) Show that the sample contains approximately 9.8×10^{15} atoms.

[1]

(ii) Show that its decay constant is 4.3×10^{-4} s^{-1}.

[1]

(iii) Calculate its activity at time t = 0 s.

activity = ... Bq [1]

(iv) Hence, calculate the time at which its activity has fallen to 8.8×10^9 Bq.

time = ... min [2]

[Total: 20]

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